

Phase Function Determination in Support of Orbital Debris Size Estimation

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To recover the size of a space debris object from photometric measurements, it is necessary to determine its albedo and basic shape: if the albedo is known, the reflective area can be calculated; and if the shape is known, the shape and area taken together can be used to estimate a characteristic dimension. Albedo is typically determined by inferring the object's material type from filter photometry or spectroscopy and is not the subject of the present study. Object shape, on the other hand, can be revealed from a time-history of the object's brightness response. The most data-rich presentation is a continuous light-curve that records the object's brightness for an entire sensor pass, which could last for tens of minutes to several hours: from this one can see both short-term periodic behavior as well as brightness variations with phase angle. Light-curve interpretation, however, is more art than science and does not lend itself easily to automation; and the collection method, which requires single-object telescope dedication for long periods of time, is not well suited to debris survey conditions. So one is led to investigate how easily an object's brightness phase function, which can be constructed from the more survey-friendly point photometry, can be used to recover object shape.

Such a recovery is usually attempted by comparing a phase-function curve constructed from an object's empirical brightness measurements to analytically-derived curves for basic shapes or shape combinations. There are two ways to accomplish this: a simple averaged brightness-versus phase curve assembled from the empirical data, or a more elaborate approach in which one is essentially calculating a brightness PDF for each phase angle bin (a technique explored in unpublished AFRL/RV research and in Ojakangas 2011); in each case the empirical curve is compared to analytical results for shapes of interest. The latter technique promises more discrimination power but requires more data; the former can be assembled in its essentials from fewer measurements but will be less definitive in its assignments.

The goal of the present study is to evaluate both techniques under debris survey conditions to determine their relative performance and, additionally, to learn precisely how a survey should be conducted in order to maximize their performance. Because the distendedness of objects has more of an effect than their precise shape in calculating a characteristic dimension, one is interested in the techniques' discrimination ability to distinguish between an elongated rectangular prism and a short rectangular prism or cube, or an elongated cylinder from a squat cylinder or sphere. Sensitivity studies using simulated data will be conducted to determine discrimination power for both techniques as a function of amount of data collected and range (and specific region) of phase angles sampled. Empirical GEODSS photometry data for distended objects (dead payloads with solar panels, rocket bodies) and compact objects (cubesats, calibration spheres, squat payloads) will also be used to test this discrimination ability. The result will be a recommended technique and data collection paradigm for debris surveys in order to maximize this type of discrimination.